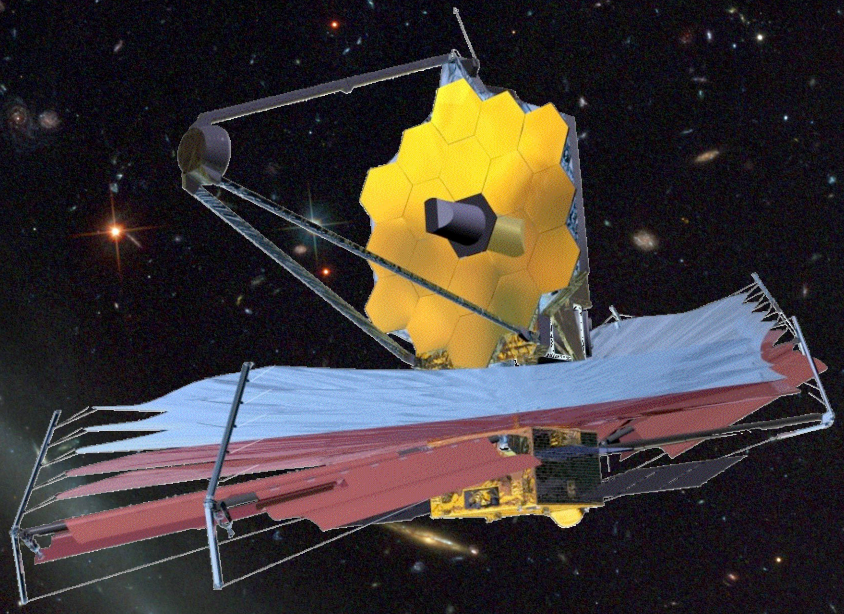
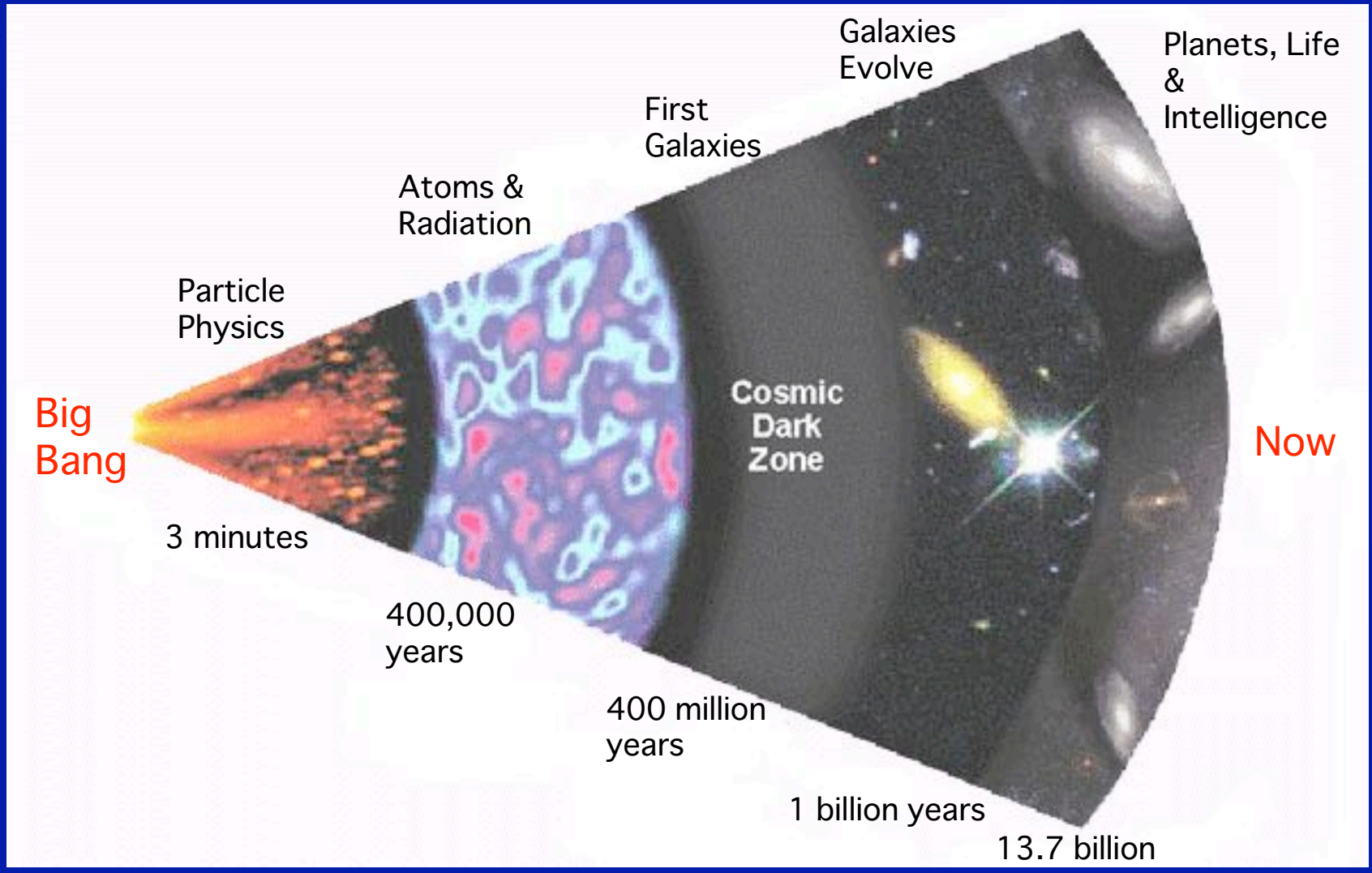
Science with the James Webb Space Telescope



Jonathan P. Gardner
NASA's Goddard Space Flight Center

A Brief History of Time



Science Themes

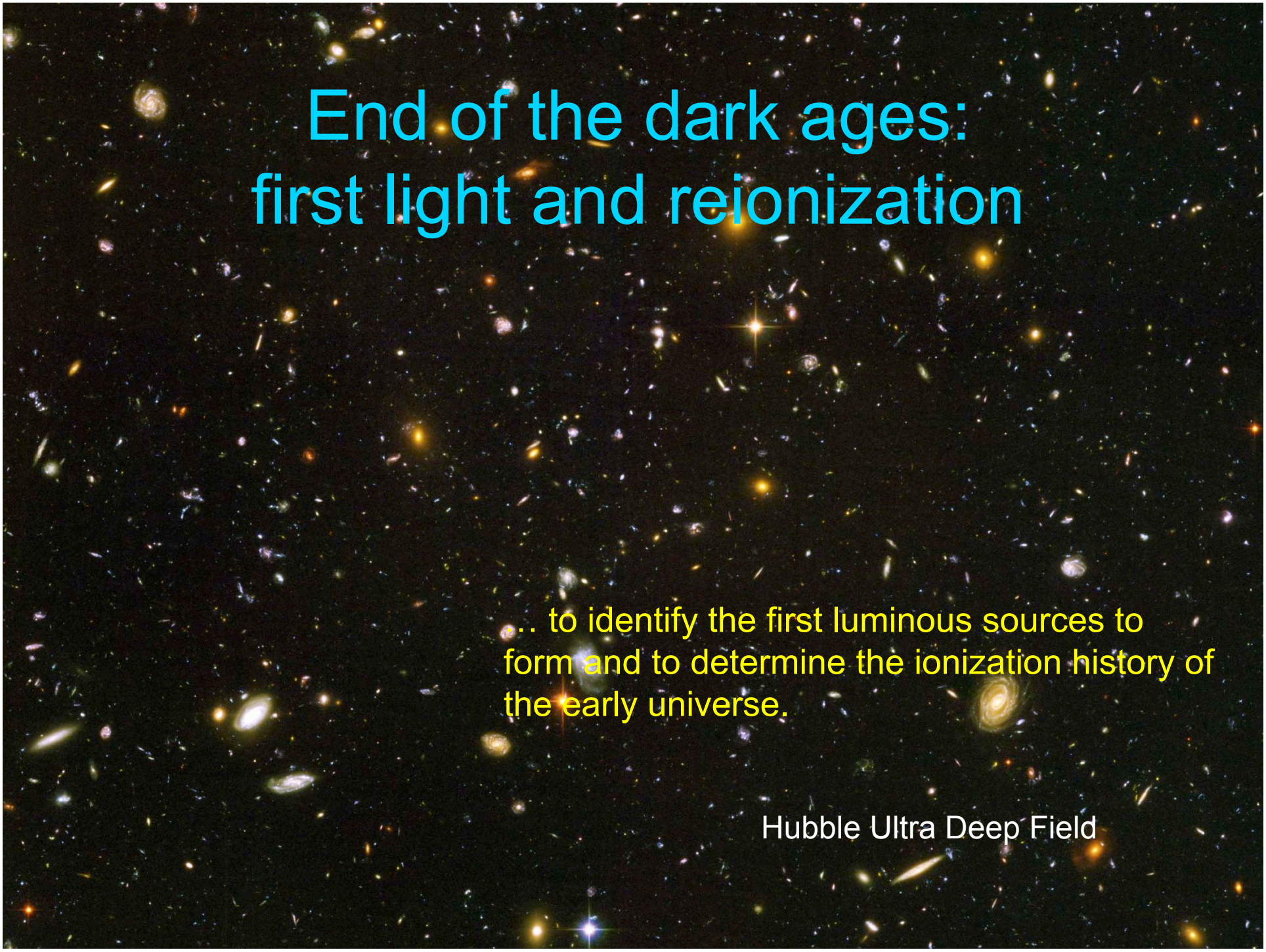
- End of the dark ages: first light and reionization
- The assembly of galaxies

Galaxies in GOODS Field

The Eagle Nebula in the infrared

- Birth of stars and protoplanetary systems
- Planetary systems and the origins of life

End of the dark ages: first light and reionization

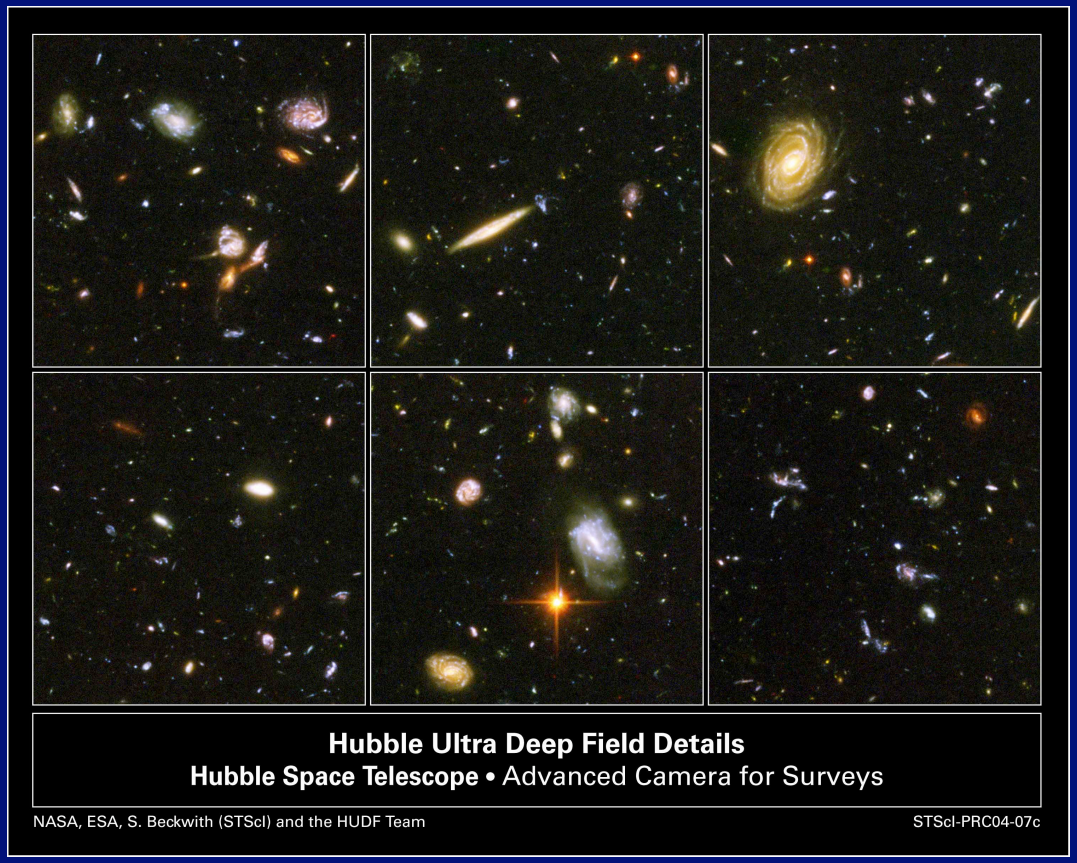


… to identify the first luminous sources to form and to determine the ionization history of the early universe.

Hubble Ultra Deep Field

What are the first galaxies?

- The first galaxies are small and faint
- Their light is redshifted into infrared.
- They are made of low-metallicity, massive stars.
  - SNe! GRBs!

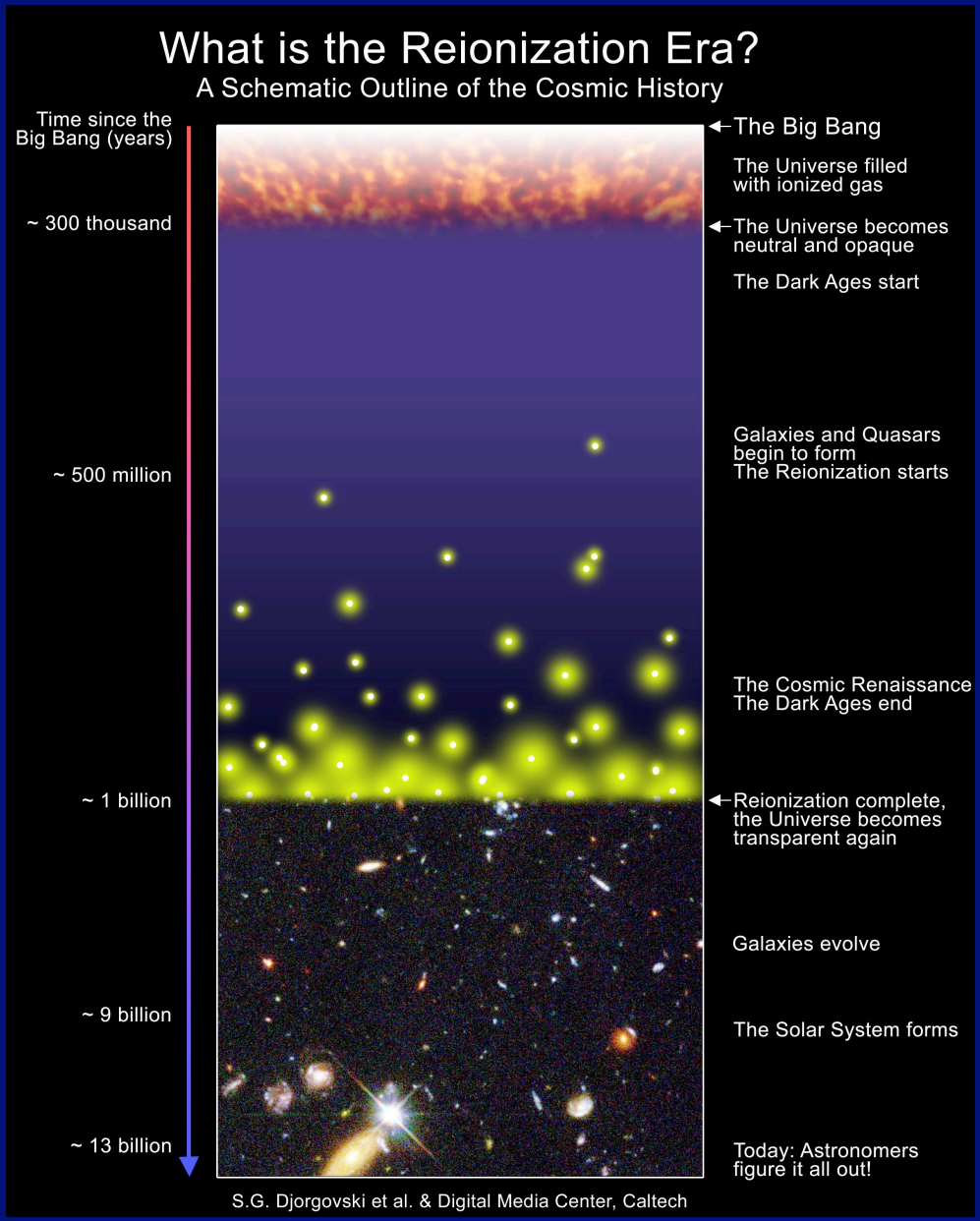


- Observations:
  - Ultra-deep NIR field
  - Follow-up Spect, MIR
  - Timing for transients

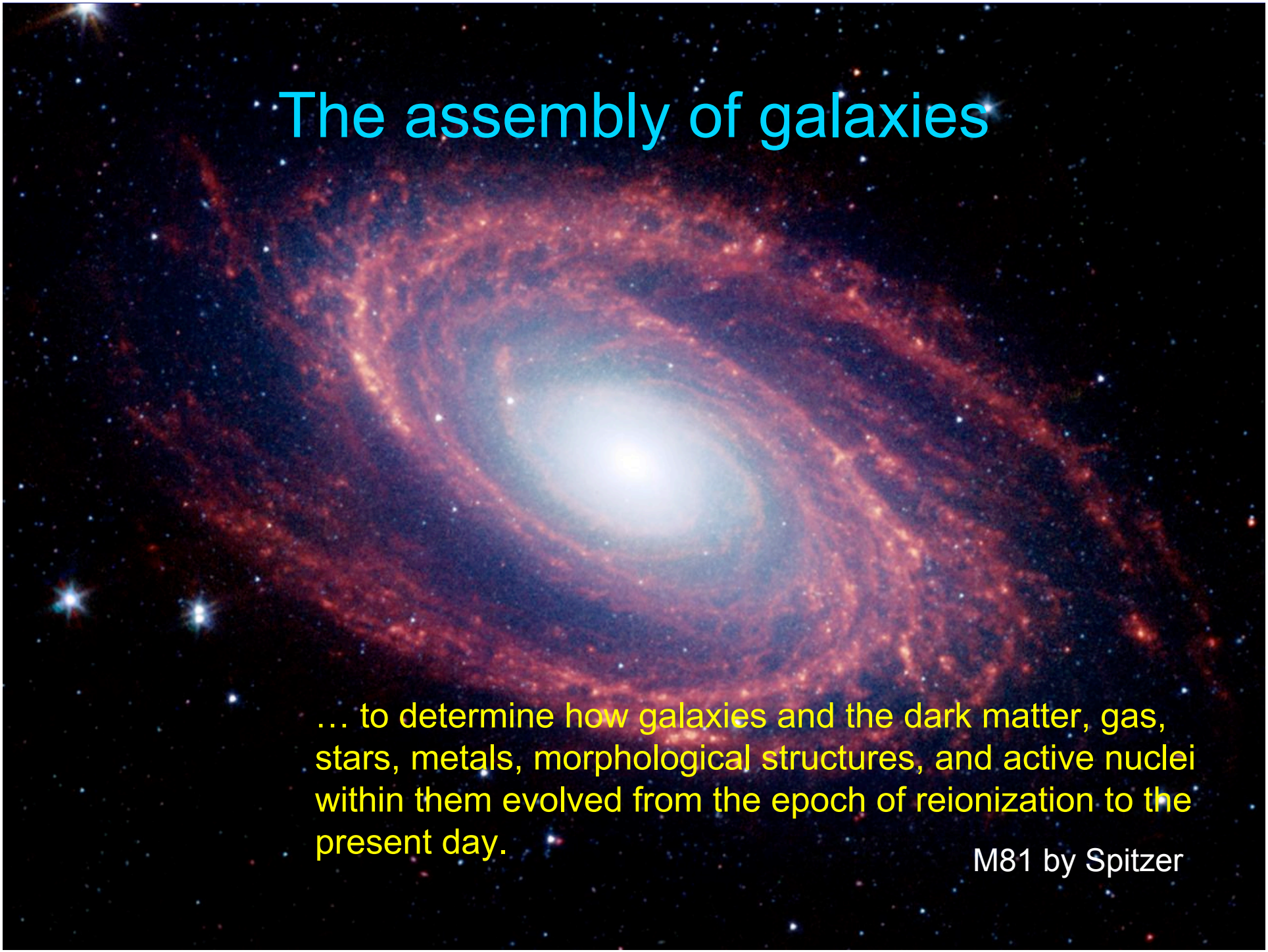
When and how did reionization occur?

- Reionization happened at z>6
- WMAP says maybe twice?
- Probably galaxies, maybe quasar contribution

- Observations:
  - Spectra of the most distant quasars
  - Spectra of faint galaxies



The assembly of galaxies

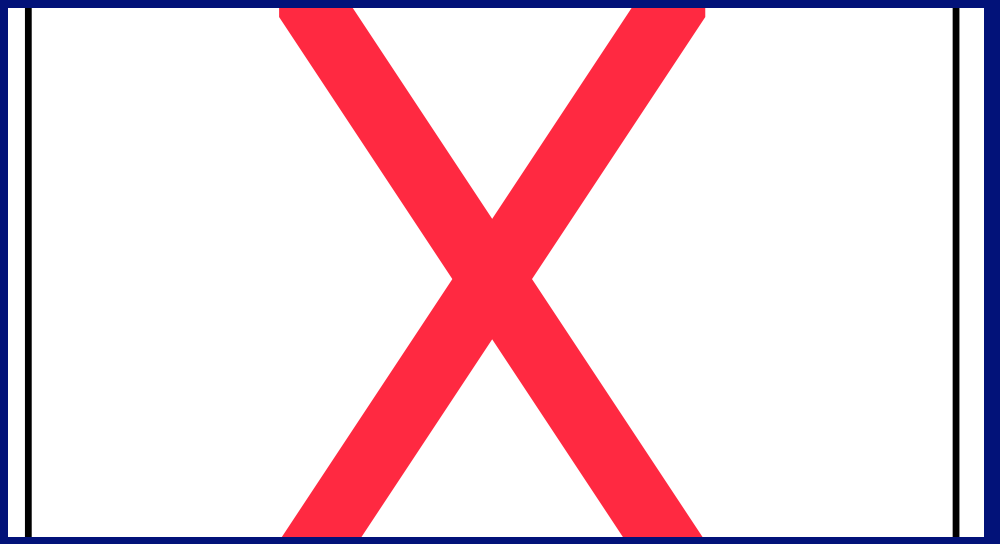


… to determine how galaxies and the dark matter, gas, stars, metals, morphological structures, and active nuclei within them evolved from the epoch of reionization to the present day.

M81 by Spitzer

Where and when did the Hubble Sequence form? How did the heavy elements form?

- Galaxy assembly is a process of hierarchical merging
- Components of galaxies have variety of ages & compositions
- Observations:
  - NIRCam imaging
  - Spectra of 1000s of galaxies



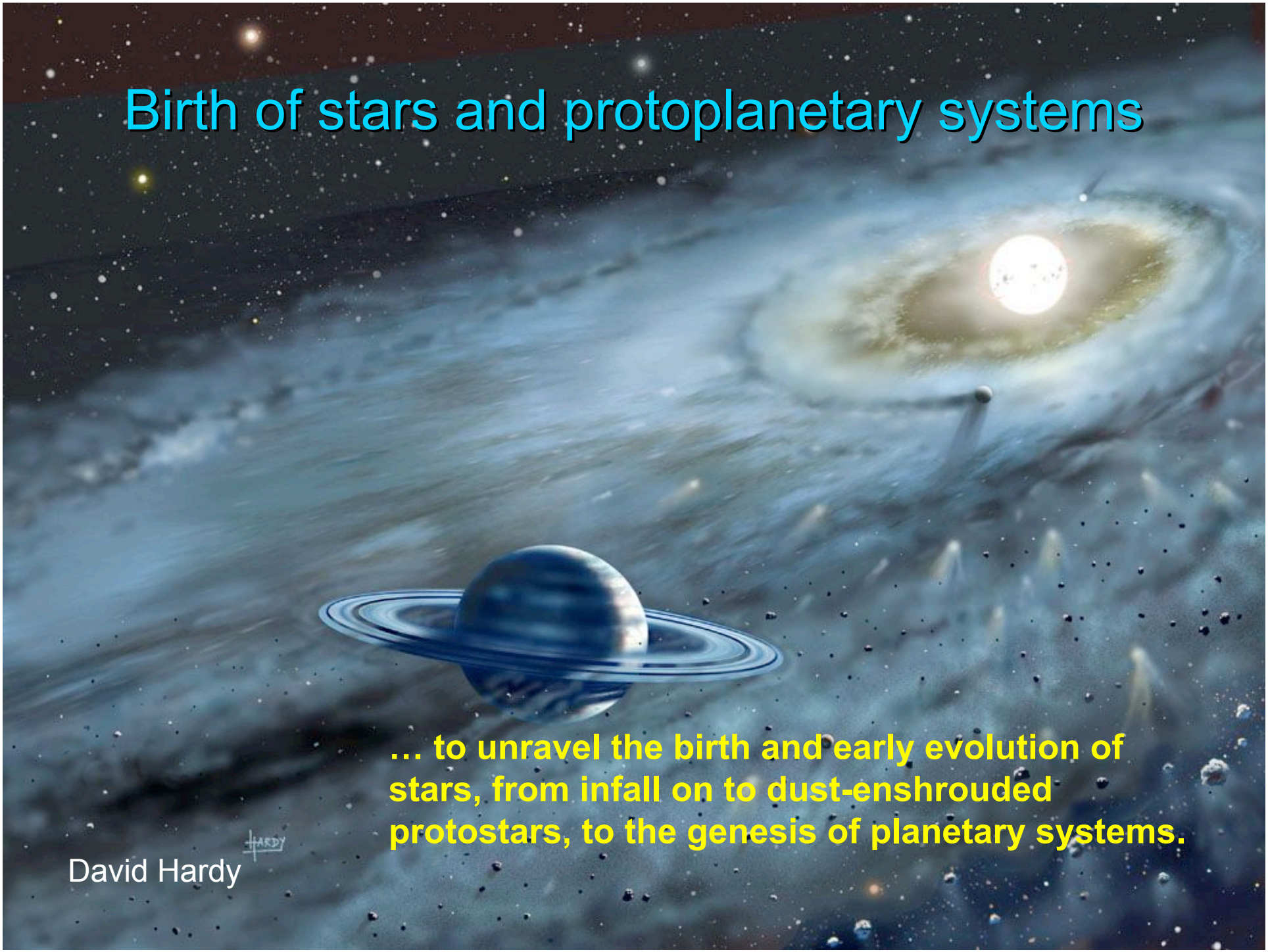
What are the physical processes that determine galaxy properties? What about starbursts and black holes?

- Observations:
  - MIR spectroscopy
  - Velocity dispersion
  - MIR emission lines

- Global scaling relations between luminosity, size, kinematics and metallicity.
- Tight correlation between mass of central black holes and surrounding galaxy

HST + radio image of active galaxy

Birth of stars and protoplanetary systems

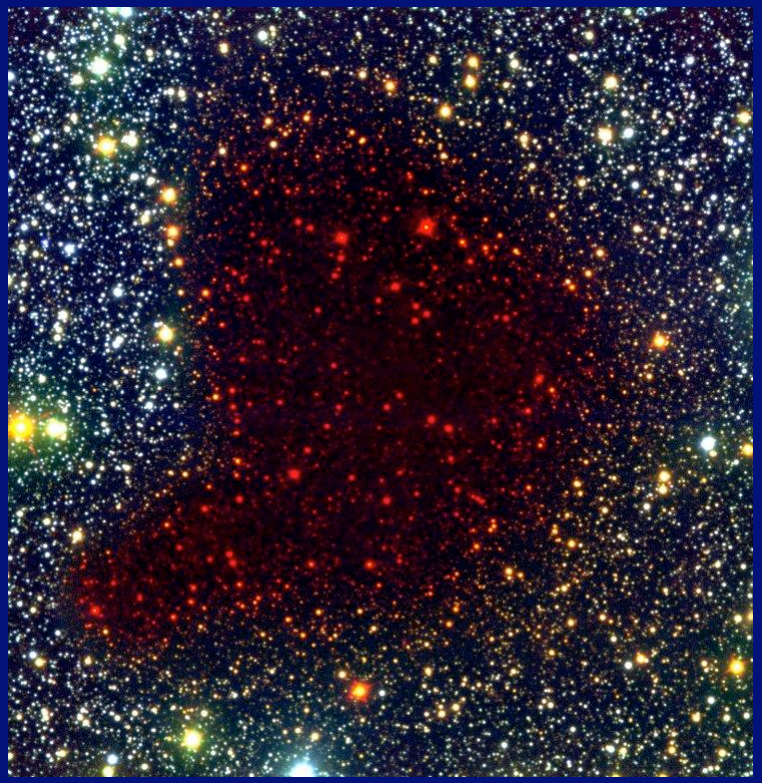


… to unravel the birth and early evolution of stars, from infall on to dust-enshrouded protostars, to the genesis of planetary systems.

David Hardy

How do proto-stellar clouds collapse?

- Stars form in small regions collapsing gravitationally within larger molecular clouds.
- We can see through thick, dusty clouds in the infrared.
- Protostars begin to shine within the clouds, revealing temperature and density structure.
- Observations:
  - Deep NIR and MIR imaging of dark clouds and proto-stars



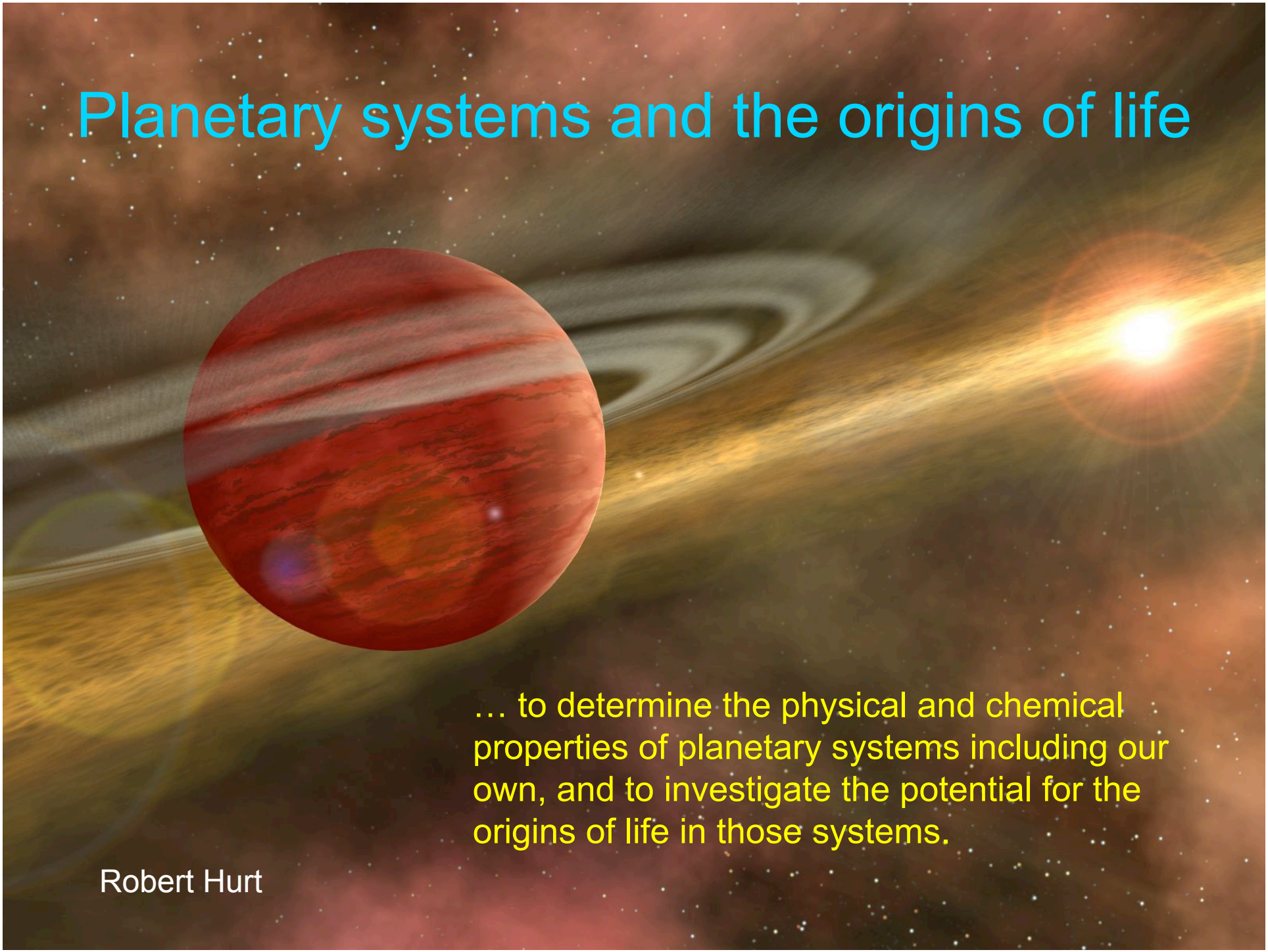
Barnard 68 in infrared

How does environment affect star-formation and vice-versa?
What is the sub-stellar initial mass function?

- Massive stars produce winds and radiation
  - Either disrupt star formation, or causes it.
- The boundary between the smallest brown dwarf stars and planets is unknown
  - Different processes? Or continuum?
- Observations:
  - Survey dark clouds, “elephant trunks” and star-forming regions

The Eagle Nebula
as seen in the infrared

Planetary systems and the origins of life

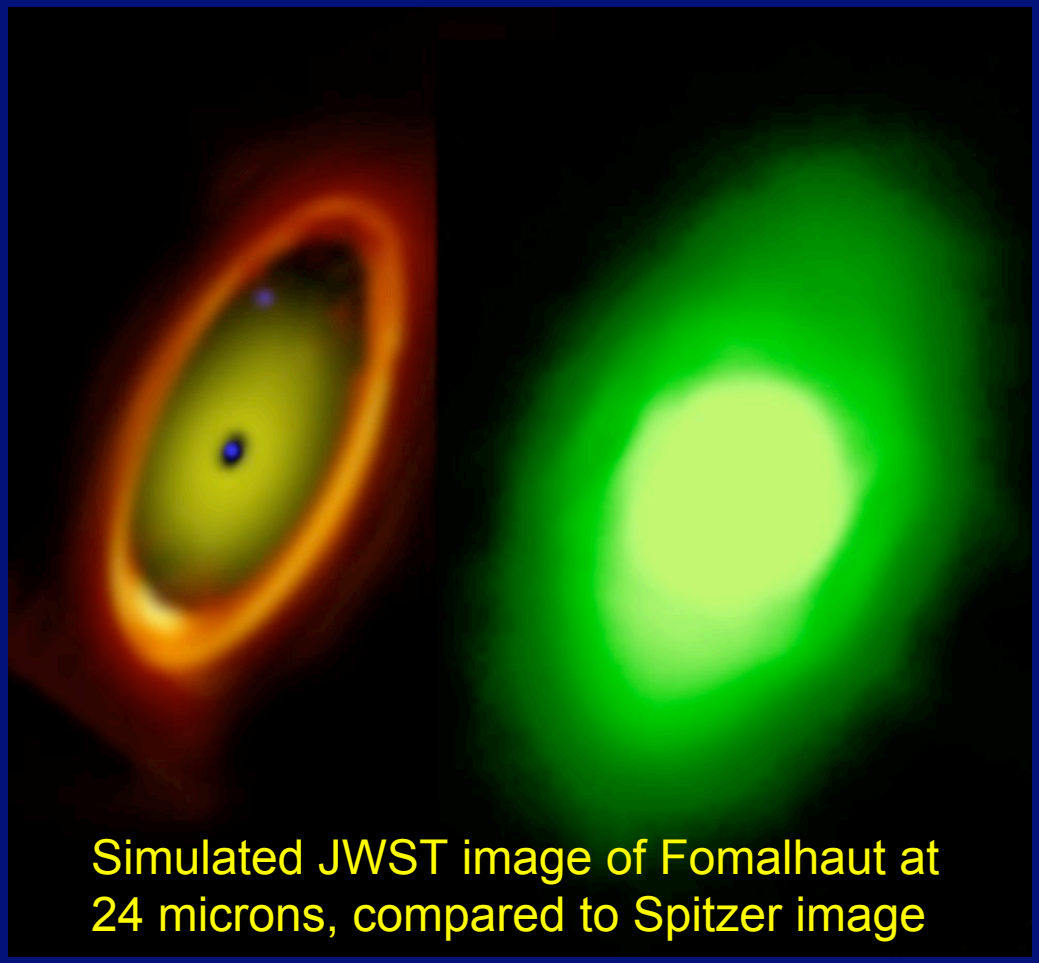


… to determine the physical and chemical properties of planetary systems including our own, and to investigate the potential for the origins of life in those systems.

Robert Hurt

How do planets form?

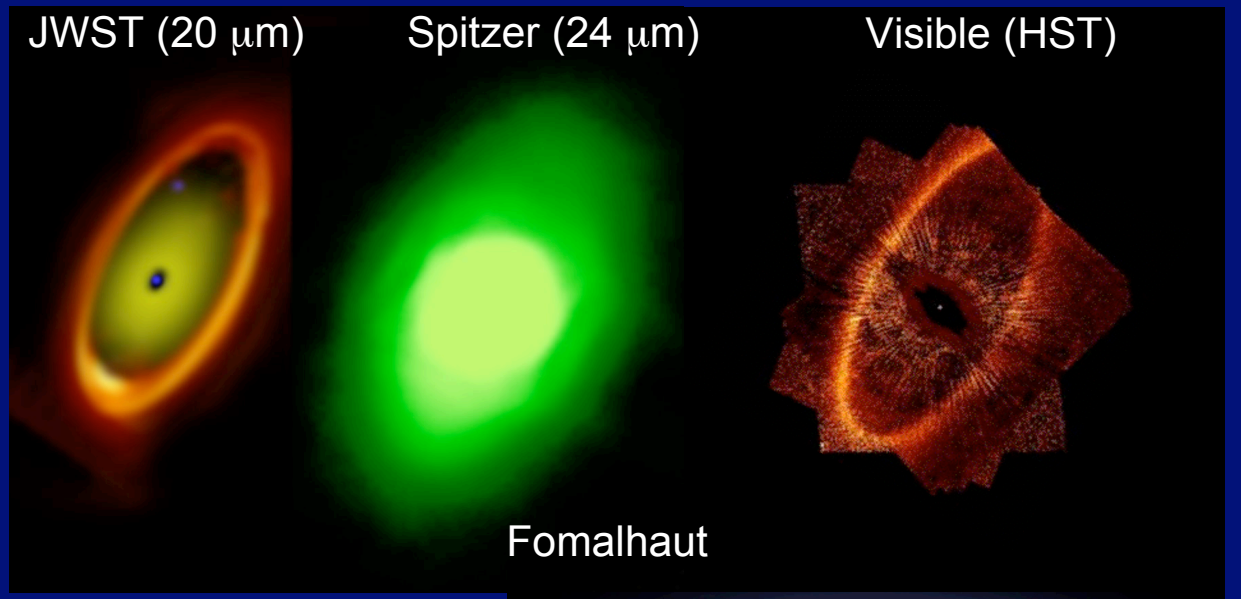
- Giant planets could be signpost of process that creates Earth-like planets
- Solar System primordial disk is now in small planets, moons, asteroids and comets
- Observations:
  - Coronagraphy of exosolar planets
  - Compare spectra of comets and circumstellar disks

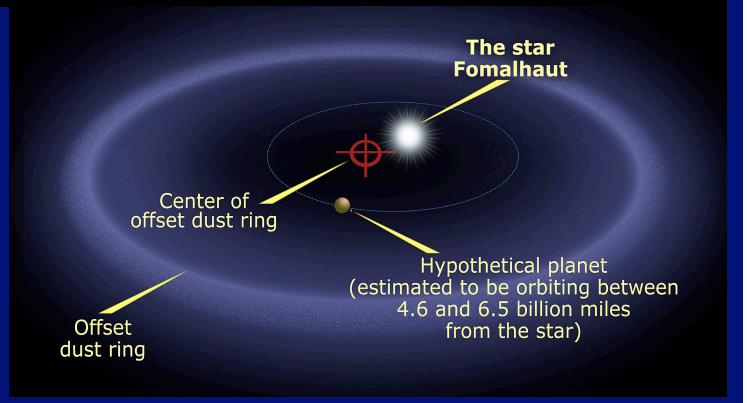


Simulated JWST image of Fomalhaut at 24 microns, compared to Spitzer image

How do planets form?

- Giant planets could be signpost of process that creates Earth-like planets
- Solar System primordial disk is now in small planets, moons, asteroids and comets
- Observations:
  - Coronagraphy of exosolar planets
  - Transiting planets
  - Compare spectra of comets and circumstellar disks

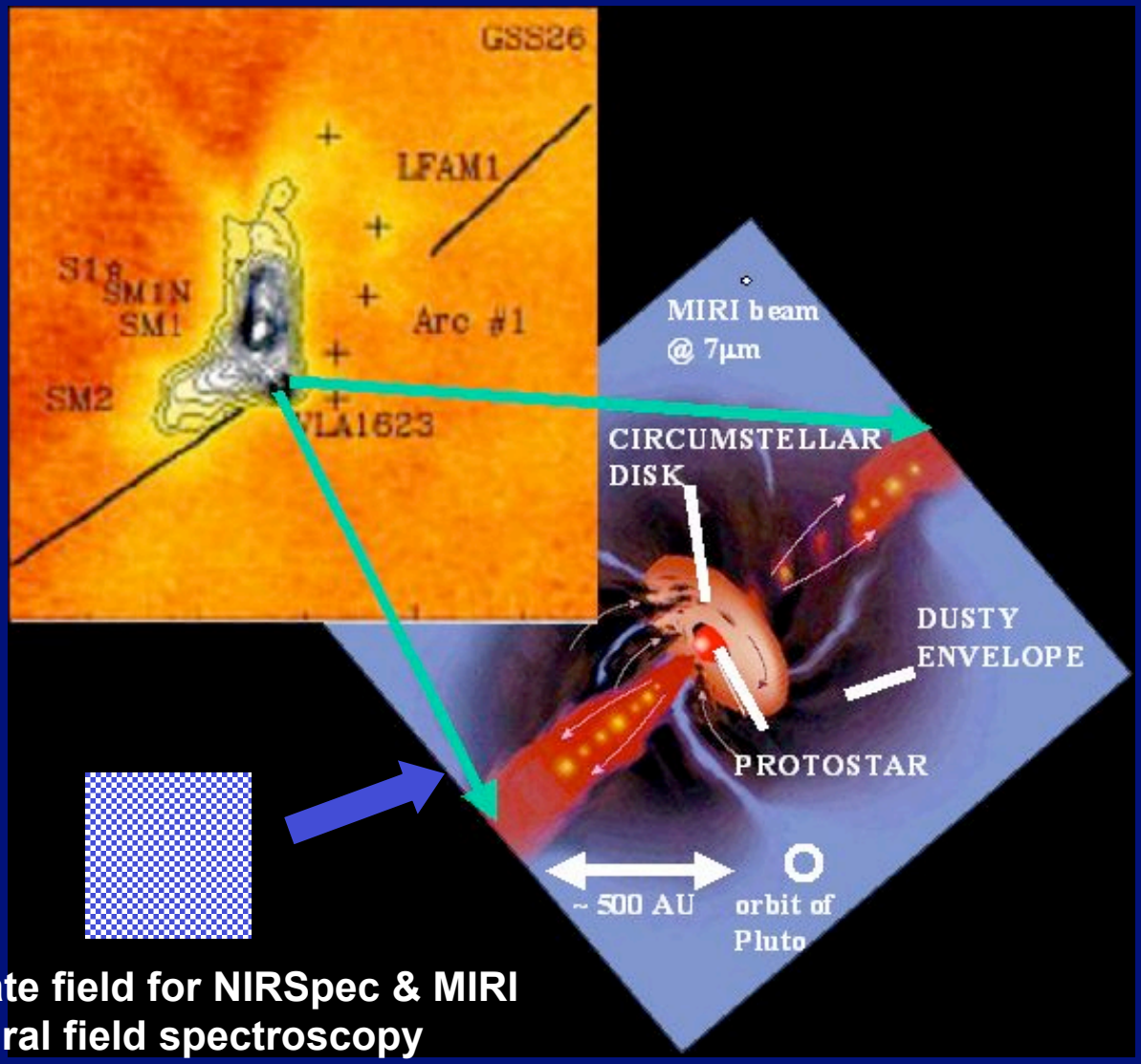




How are circumstellar disks like our Solar System?

Here is an illustration of what MIRI might find within the very young core in Ophiuchus, VLA 1623

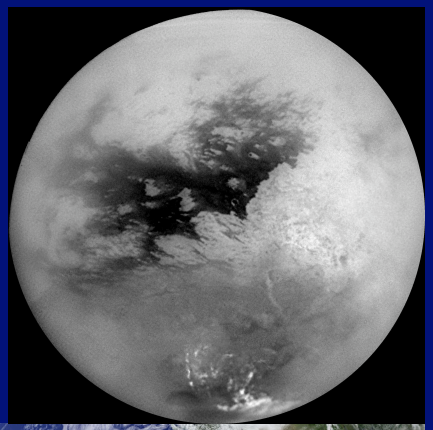
artist's concept of protostellar disk from T. Greene, Am. Scientist



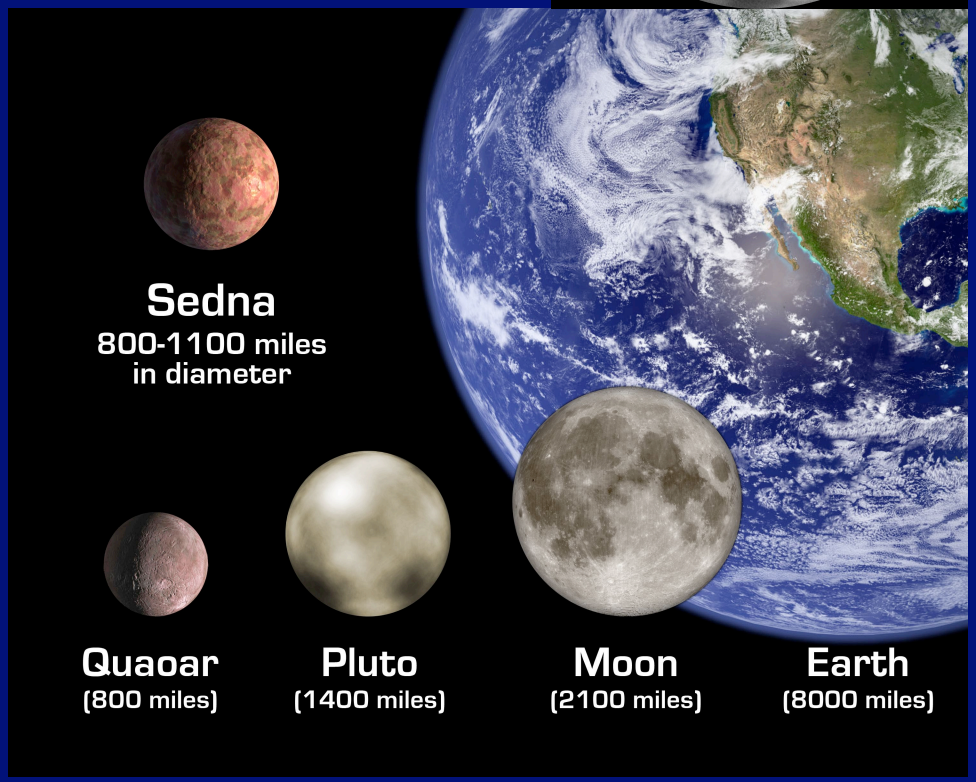
approximate field for NIRSpec & MIRI integral field spectroscopy

How are habitable zones established?

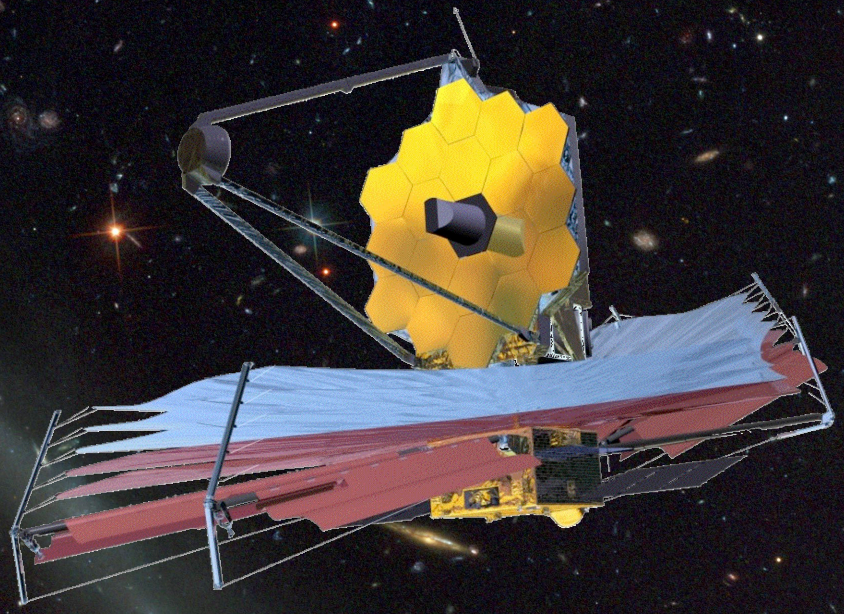
- Source of Earth's H_20 and organics is not determined
  - Comets? Asteroids?
- History of clearing the disk of gas and small bodies
  - Role of giant planets?
- Observations:
  - Comets, Kuiper Belt Objects
  - Icy moons in outer solar system



Titan



Science with the James Webb Space Telescope



Jonathan P. Gardner
NASA's Goddard Space Flight Center